ilc resources

MINERAL *Writes*

1st QUARTER 2013

In this issue:

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Influencing Calcium & Phosphorus Digestion

Digesting feed starts as soon as animals take the food in their mouth. The process of digestion breaks down the feed and releases the nutrients all along the gastrointestinal tract. Certain conditions, dietary supplements and sources of nutrients interact and can affect where, when and how much of the necessary nutrients are released into the animal's body.

Specifically, calcium is absorbed in the small intestine when it is dissolved in the somewhat acidic medium of the digestive tract. How much of this nutrient is available depends on the source and particle size of the dietary calcium, how long the nutrient is retained in the gastrointestinal tract and the presence of phytate. Calcium solubility is further impacted by gastric acid secretion and pH of the digestive tract. Many studies have proven that calcium solubility is reduced when gastric secretions are inhibited and the pH is increased (more basic). Calcium retention in the gastrointestinal tract can be reduced as calcium particle size increases, but is not affected by the calcium solubility according to a study by Guinotte et al., 1995. Thus, the role of dietary phytate/phytase is also important due to interaction with pH, retention time and nutrient solubility.

Dietary phytate precipitates and binds with calcium in the small intestinal medium. This makes calcium-phosphate complexes that are not soluble. Phytase hydrolyzes phytate, and improves calcium and phosphorus digestion. Commercially available phytases are active in the upper portion of the gastrointestinal tract, but not throughout the entire tract. In poultry, the small intestine lumen contains minor concentrations of endogenous phytase and in pigs alkaline phosphatase is expressed. The presence of dietary calcium reduces the efficacy of these endogenous phytases.

All this means that the solubility and digestibility of calcium and phosphorus in poultry and pigs (monogastrics) is influenced by the conditions in the gastric phase of digestion, the pH, the retention time, the dietary source and particle size, and the presence or absence of phytate that endogenous phytase acts upon.

What the Research Found

Walk et al., (2012), conducted an in vitro (artificial environment) study looking at all of these effects in diets fed to broilers. They used dicalcium phosphate and calcium carbonate in experimental diets that contained 0.89% Ca and 0.40% available P (positive control) or 0.76% Ca & 0.27% available P (negative control). These sources of calcium and phosphorus or antacids, at the low pH levels of a gastrointestinal tract are such that the calcium may bind with hydrogen ions which increased pH levels in the positive control diet that contained more of these dietary calcium sources. The positive control diet had 66% more dicalcium phosphate and 24% more calcium from calcium carbonate in comparison to the negative control diet. This study duplicated findings where pullet gizzard pH increased from 2.76 to 3.82 when dietary calcium increased from 1 to 3.6% (Guinotte et al., 1995).

Phytase was added to both the positive & negative control diets

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Benefits to Feeding Fermented Soybean Meal?

Most of the phosphorus in soybean meal is bound in the phytate complex. Adding microbial phytase may increase the apparent total tract digestibility and standardized total tract digestibility of phosphorus in soybean meal.

There is growing interest in feeding fermented soybean meal as a replacement for fish meal in the swine and poultry industries. The bioavailability of phosphorus is expected to be greater in fermented soybean meal than in conventional soybean meal similar to the conditions found in corn distillers dried grains with solubles. Current research has not demonstrated this fact yet (Hong et al., 2004).

The study by Rojas and Stein (2012) looked at the digestibility of phosphorus in pig diets fed either conventional or fermented soybean meal with and without added microbial phytase. The total amount of phosphorus in fermented soybean meal was .78% compared to .66% in conventional soybean meal and the concentration of phytate was less in fermented soybean meal (1.38% compared to 1.51%). When pigs were fed conventional soybean meal and phytase, daily phosphorus intake was significantly less ($P < 0.05$) than in pigs fed conventional soybean meal without phytase. In the diets containing fermented soybean meal, the daily absorption of phosphorus was greater than in diets containing conventional soybean meal. Phosphorus absorption was also greater when phytase was used compared with no phytase regardless of the soybean source.

In terms of calcium digestibility, pigs fed fermented soybean meal without phytase digested less calcium. The study showed a significant interaction between the source of soybean meal (conventional vs. fermented) and phytase. Pigs digested and utilized more calcium when they were fed fermented soybean meal with phytase. The supplemental phytase increased calcium utilization in the diets containing conventional soybean meal, but not as much as in the fermented soybean meal diets.

For reference, soybean meal contains both phytate-bound and non-phytate bound phosphorus. In conventional soybean meal, the concentration of phytate bound phosphorus is greater than in fermented soybean meal. The fermentation process removes carbohydrates and thereby increases the concentration of crude protein, NDF, phosphorus, and other nutrients including amino acids. The fermentation process of soybeans is similar to fermenting corn in the ethanol process. The digestibility of phosphorus in fermented corn is also greater than in conventional corn and nonfermented coproducts. Thus fermentation, improves the phosphorus digestibility of feed ingredients which contain phytate bound P.

By adding phytase to conventional soybean meal which has a greater concentration of phytate-bound phosphorus, more phytate is hydrolyzed than would be in fermented soybean meal. This also increases the digestibility of phosphorus in the conventional soybean diets.

Practical Application – What this means

What this means for producers is that adding phytase is going to have varying effects on the diet depending on the feedstuff ingredients. When there is more phytate-bound phosphorus in the diet, the supplemental phytase will generate a greater response in releasing phosphorus. If diets are formulated using a constant value for phosphorus release when using supplemental phytase, regardless of ingredients used, the numbers may not yield an accurate measure of available phosphorus. In addition, there appears also to be an interaction with age of pigs (?) in this balance as the digestibility of phytate-bound soybean meal improves as the pig ages.

The apparent total tract digestibility of calcium increases as phytase is added to the diet regardless of the source of the soybean meal. This is probably because phytase reduces the amount of phytate in the intestine and reduces the capacity of the phytate to chelate (or bind) calcium, ultimately increasing the amount of now available calcium.

The person formulating the diets must consider the source of the ingredients (fermented or not). Fermented grain (corn or soybeans) contains more total tract digestible phosphorus. By adding supplemental phytase to conventional soybean meal, the amount of total tract digestible phosphorus is equivalent. Also, if the fermented source contains more digestible phosphorus, less inorganic phosphorus may need to be added to the diet.

Information taken from:

Rojas, O.J. and H.H. Stein. 2012. Digestibility of Phosphorous by Growing Pigs of Fermented and Conventional Soybean Meal Without and With Microbial Phytase. *Journal of Animal Science.* 90:1506-1512. Doi: 10.2527/jas2011-4103.

Hong, K.J., C.H. Lee, and S.W. Kim. 2004. *Asperfillus oryzae* GB-107 fermentation improves nutritional quality of food soybeans and feed soybean meals. *Journal of Medicinal Food.* 7:430-435.

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which resulted in increased calcium and phosphorus hydrolysis.

Over the course of digestion, the solubility of these nutrients reached a plateau in its improvements. In the artificial environment of the study, the increased calcium and phosphorus solubility was found in both the gastric phase (simulating the stomach) and continued through to the small intestinal phase of the digestion study. Since phytase is active in the acidic pH of the gastric phase, the release of soluble calcium ions and interference with protein solubility may be contributing factors in raising pH through to the small intestinal phase and reduce the digestibility of other minerals and amino acids in nonruminants. In this part of the study, no additional release of minerals occurred in the small intestinal phase in the presence or in the absence of the phytase.

Under the same conditions and using the same solutions, a second experiment was conducted to determine the effects of time on the solubility of calcium and phosphorus in the in vitro gastric phase. In the absence of phytase in the experiment, phosphorus solubility did not change over time and the solubility rate was between 43 and 50% of the total phosphorus in the diet. When phytase was introduced, the phosphorus solubility increased significantly. Within five minutes of starting the incubation, phosphorus solubility was improved and continued for up to 20 minutes after the experiment was stopped. Particle size of the phosphorus affected solubility, and there was a diet x particle size interaction. Larger particle sizes (ground to pass a 2-mm screen) were less soluble than smaller ones. However, after 10 minutes in the presence of phytase, the larger particles increased in solubility. This is also evidence of a particle size by incubation (digestion) time interaction.

Calcium solubility was influenced by phytase, with the effects dependent on the particle size and incubation (digestive) time. The same interactions between diet and particle size and between particle size and incubation time (of phosphorus) were found in the experiment for calcium. However, if the particle size is fine, the calcium is extremely soluble and may rebind with the phytate molecule and ultimately pass through the animal's system. A 2006 article in *Mineral Writes* summarized a study conducted at the University of Arkansas by Dr. Megharaja Manangi and Dr. Craig Coon. This study specifically asked if the particle size of the calcium source and solubility decrease the amount of phytic acid which forms the mineral phytate complex and then results in a maximum response of the phytase enzyme and more available phosphorus for growth and bone formation in poultry.

Earlier research showed that: a) the amount of calcium in a broiler diet affects the use of phytase, b) the solubility of phytic acid (phytate) in feed ingredients is affected by pH, and c) phytate phosphorus utilization is affected by calcium ion concentrations in the small intestine where insoluble calcium-phytate complexes form. Specifically, Zhang and Coon (1997) reported that calcium solubility and retention in the gizzard was increased in laying hens fed feeds containing large particles of the calcium source. Differences between laying hens and broilers need to be considered here. Laying hens are efficient at digesting calcium from the diet and in mobilizing calcium from the medullary bone. This is a requirement for egg shell formation, and may mean that laying hens are better able to withstand inconsistent calcium supplies from the diet. With broilers, using finely ground calcium (Unical S, for example) in the presence of phytase may improve the nutrient solubilization and bone health by improving calcium availability and digestibility.

What this means for the industry

It is important to remember that this experiment was conducted in an artificial environment and this limits the extent of any inferences about conditions within the animals. Regardless of the limitations, this study emphasizes the importance of pH, retention time, particle size and how the use of phytase affects calcium and phosphorus solubility. All of these factors vary among individual animals, particularly poultry, and each animal has different nutrient requirements because of these factors. As a result, these individual differences between the birds' body weights may be why a reported uniform body weight is reduced when all birds are fed a common diet.

By understanding how each of the factors (the influence of phytase, pH, and retention time) affects calcium and phosphorus solubility throughout the entire gastrointestinal tract, a digestible calcium requirement may be able to be established, much like the digestible phosphorus requirements that have been determined. Establishing this requirement may ease the need for increased dietary calcium, which then might save space in the diet and improved nutrient utilization and bird health.

In terms of particle size and solubility, Table 1 on page 4 shows the various ILC Resources calcium carbonate products, their particle size and solubility. In broilers and pullets, a large particulate size (i.e., the 1160 micron size of Unical L) will solublize Ca^{++} too slowly and therefore pass through the GI tract with very little absorption. As stated above, the smaller particulate size (10 micron of Unical P or 6 micron size of Unical UF) are also not ideal, since they are more soluble, so the calcium passes through quickly and then rebinds with the phytate molecule, making it undigestible.

Again, since there are many variables, (calcium and phosphorus source, particle size and retention time and the influence of phytase) it may be convenient if a product like Fre Flo or Unical S is used since they are the right particle size and solubility. These two

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products match up well with this study to maximize feed efficiency for pullet or broiler diets.

Information taken from:

"Influence of diet, phytase, and incubation time on calcium and phosphorous solubility in the gastric and small intestinal phase of an in vitro digestion assay." Walk, C.L., M.R. Bedford, and A.P. McElroy. 2012. *Journal of Animal Science*. 90:3120-3125.

"Calcium solubilisation and retention in the gastrointestinal tract in chicks (*Gallus domesticus*) as a function of gastric acid secretion inhibition and of calcium carbonate particle size." Guinotte, F., J. Cautron, Y. Nys, and A. Soumarmon. 1995. *British Journal of Nutrition.* 73:125-139.

"The relationship of calcium intake, source, size, solubility in vitro and in vivo gizzard limestone retention in laying hens." Zhang, B. and C.N. Coon. 1997. *Poultry Science*. 76:1702-1706

"Evaluation of phytase enzyme with chick fed basal diets containing different soybean meal samples." Manangi, M.K. and C.N. Coon. 2006. *Journal of Applied Poultry Research* 15: 292-306.

Table 1

Product	Particle Size Description	Micron Size	Mesh Size	% Acid Solubility
Unical F	Large Granule	2200	9	41.4
Unical L	Large Granule	1160	16	45.2
Fre Flo	**Blend Small to Large**	**520**	**35**	**51.2**
Unical S	**Small Granule**	**190**	**80**	**58.3**
Unical P	Finely Ground Powder	10	1700	77.3
Unical UF	Finely Ground Powder	6	2300	65.5

ILC Resources' mission statement declares:

"ILC is committed to providing the highest quality products and to be striving for continuous improvement. We are dedicated to consistently exceed our customers' expectations of service and quality at every opportunity." Our people make this happen.

Solid as a Rock for 60 Years

While many *Mineral Writes* articles focus on calcium carbonate as a feed ingredient, another product option is Dairy-White Sweet Barnlime. With the unique screening and blending process used by ILC Resources, two grades of Dairy-White Barnlime are produced. One is a "coarse" grade and the other is "regular."

The product has four distinct benefits when it is used, regardless of grade (coarse or regular). The product adsorbs moisture, reduces odors, enriches manure and is non-caustic to animals and humans. The Barnlime is thoroughly dried as part of the ILC Resources production, which makes it such an effective adsorbent. The risk of slippage and injuries is reduced when the product is applied to barns, loafing sheds, farrowing houses, pet areas, horse stalls, alleyways, poultry house and many other livestock facilities. The coarse particles provide traction and the regular (smaller) particles adsorb the moisture.

Secondly, the Barnlime acts to chemically neutralize acid thereby reducing odors. By "sweetening" the air in a livestock barn, it may be obvious where the inspiration for the "Sweet" name came from. In addition, by enriching the manure with this product, when it is applied to fields, the soil is fertilized and the soil acidity is reduced. This contributes to moving the soil pH to a more optimum level for nutrient uptake, which occurs at a greater rate closer to a more neutral pH between 6.0 and 6.5. While obviously attractive to livestock operations, this fact makes agronomic sense for crop production.

It is also important to remember that Dairy-White Sweet Barnlime is non-caustic to either livestock or humans. This means the product is environmentally harmless and safe to use in areas mutually utilized by animals and humans.

Dairy-White Sweet Barnlime is used in more than just dairy operations. It has been and is used in swine, poultry and a wide variety of other animal facilities. The product reduces the instance of slipping and risk of subsequent injury by adsorbing moisture, "sweetens" the air by neutralizing odors from the build-up of animal wastes, and by enriching that manure and then, when added to the fields, enriches the soil. This is an ideal environmentally friendly product, non-caustic to humans and animals and has been proven beneficial time and time again over the 60+ years of its production by ILC resources.

Information for this article taken from *Mineral Writes*, 2nd Quarter, 2004 and 3rd Quarter, 2006